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SCANNING PATTERNS IN APHASIC PATIENTS DURING MATCHING-TO-SAMPLE TESTS*

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Abstract—Aphasic patients showed altered scanning of a visual display in a matching-to-sample task when only the type of sample stimulus was varied. The patients glanced more frequently at the correct choice during the performance of tasks on which error scores showed that they were deficient. Scanning changes occurred even on tasks which the patients performed errorlessly at the time of testing, but on which they had previously shown difficulty. Scanning patterns were thus more sensitive than error scores in detecting language difficulty.

INTRODUCTION

THE MEASUREMENT of eye movements has found wide application in studies of pattern perception, reading skills, and more recently aphasia. Eye movements have been monitored in aphasic patients while they were scanning complex visual forms [1], but not during specific language tasks. One reason for the absence of such studies has probably been the difficulty in communicating with patients who are deficient in speech or comprehension. We have found it possible to study language behavior even in severely aphasic patients by means of an automated matching-to-sample procedure that does not require oral communication between subject and experimenter [2]. The subject receives auditory (dictated) or visual sample stimuli to which he responds by selecting an appropriate matching stimulus from a display of several choices; the consequences (reinforcement or nonreinforcement) of his choices inform him of the accuracy of his selections. He may, for example, be required to choose an appropriate picture in response either to a dictated or a printed sample word. In the present study, we monitored eye movements while the patients were scanning the choice display, and were able to compare scanning patterns across several types of language and nonlanguage tasks. We found that aphasic patients scanned the same display of visual choices differently, depending only on the type of sample to which they had to respond.

METHODS

The subjects sat before a display panel of nine 5×5 cm^2 windows arranged in a 3×3 matrix. The subject's chin rested in a head rest assembly (Biometrics Co., Cambridge, Mass.) with the matrix subtending

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approximately 18° of his visual field. Samples—visual stimuli projected onto the center window of the matrix, or auditory stimuli dictated via an endless loop tape system [3]—were single letters, 3-letter words, 3-consonant trigrams, or pictures. Following free listening to or viewing of a sample, the subject pressed the center window, causing the sample to vanish and the choices to appear immediately in the outer windows (delayed matching). The subject indicated his selection by pressing a choice window, and, if correct, was rewarded by the sounding of chimes and the delivery of a nickel or dime. Each matching test had 20 trials (2). An infra-red, corneal reflection apparatus (Biometrics Co., Cambridge, Mass.) monitored the subjects' eye movements and activated a chart recorder which plotted vertical and horizontal movements separately. We then manually converted into scanning patterns those eye fixations which occurred while the subject was scanning the choice display. Any movement which brought the subject's gaze to rest on a choice was counted as a "fixation"; smaller movements within a single choice window were not tallied.

None of the patients exhibited visual field defects or visual neglect.

RESULTS

On the more difficult matching tasks (as indicated by higher error scores) the patients, as might be expected, revealed their uncertainty by glancing several times at the individual stimuli in the display before choosing one. The increased number of fixations during these tests was apparent even on trials when they chose correctly. This led to the suggestion that scanning patterns might be more sensitive than error scores in detecting language impairment. The suggestion was buttressed by the finding that the patients also fixated the display stimuli more frequently during some tasks on which they made few or no errors; here, the altered scanning seemed related to difficulties the patients had manifested during these tests in the past, but on which their performance had improved. The patients' "uncertainty" was especially apparent when we considered only the number of times they fixated the correct choice before actually selecting it. Figure 1, therefore, presents the number of fixations per trial on the correct choice only, and only for those trials on which the patients chose correctly. Error scores are also indicated.

The first patient, R.W., was a 20-year old, right-handed male who had suffered an acute cerebrovascular accident at age 14, with arteriographic demonstration of left middle cerebral artery occlusion. The patient was globally aphasic following this episode, with no oral speech. Gradually his comprehension of spoken language improved clinically, leaving a predominantly Broca-type, expressive aphasia. When first tested one year after the initial episode he made numerous errors on tasks involving dictated-spelled sample words, but he matched printed and pronounced word samples to visual choices (words and pictures) nearly errorlessly. Surprisingly, he had more difficulty with dictated single-letter samples than with pronounced words [4]. Over the next five years, these early deficiencies gradually improved [5]. His error scores and eye-fixation frequencies at the time of this study are in the top row of Fig. 1.

The four bars at the upper left show Patient R.W's fixations on the correct choice, on correct trials only. The choice display always consisted of eight three-letter words; the only difference in the four test procedures was the type of sample stimulus to which the patient had to respond. He rarely glanced more than once at the correct word when the samples were visual words or pictures but showed an increased number of fixations in response to pronounced words, and still more to spelled words.

Error scores were relatively high in response to spelled words, but not to pronounced words. This suggests that if the patient had originally been tested sooner after his stroke, he might have been deficient in matching pronounced to printed words, a deficit which now appeared residually in his eye movement patterns. The suggestion is supported by the patient's different patterns of scanning single-letter displays in response to printed and dictated single-letter samples. He was originally grossly deficient in the auditory-visual

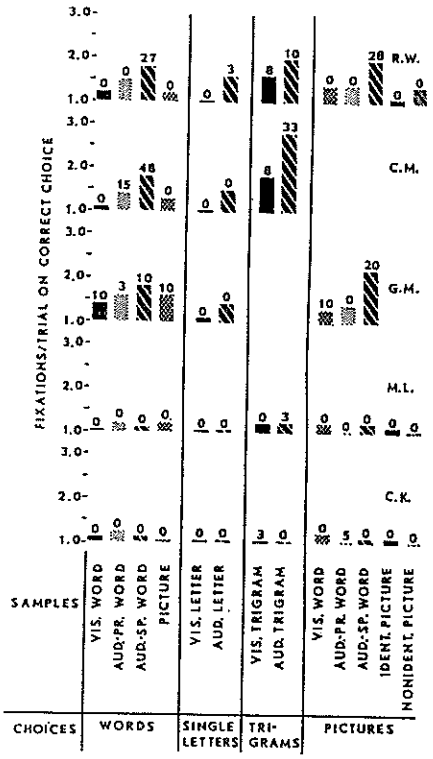

FIG. 1. Average number of fixations per trial on the correct choice, for correct trials only, by three aphasic patients (R.W., C.M., and G.M.) and two normal control subjects (M.L. and C.K.). The sample and choice stimuli in each type of test are indicated below each column of bars. The number above each bar denotes the percentage of trials on which the subject made errors.

matching of single letters, but the early deficit had nearly disappeared when measured by error scores. Scanning patterns, however, suggest a continuing residual deficit. The patient's scanning of three-consonant trigrams showed the same increase in correct-choice fixations as the sample switched from the visual to the auditory modality, even though the error scores were nearly identical.

In tests which required the patient to make a selection from a display of eight pictures, he showed the largest number of fixations on the correct choice, and the most errors, when the samples were dictated–spelled words (Fig. 1). The slightly elevated number of fixations when the samples were printed or dictated–pronounced words—tests on which he had never had difficulty in the past—resulted not from the language nature of these tasks, but simply from the fact that samples and correct choices were not physically identical. When the samples were pictures identical to the correct choices, the patient rarely fixated on the correct choice more than once; nonidentical sample and choice pictures produced the same fixation frequency as printed and pronounced words.

The second patient, C.M., was a 49-year old right-handed male who also suffered an acute left middle cerebral artery occlusion; this patient, like the first, showed a predominantly Broca-type aphasia, with milder difficulty in language comprehension. This patient was tested from 1½ to 6 weeks after his stroke. Like the first patient, he made more fixations

on the correct choice in the auditory-visual tasks. Even in the letter–letter task, on which he had shown no deficit, he glanced at the correct letter more frequently after an auditory than after a visual sample. The number of fixations decreased steadily as the patient improved (not shown in Fig. 1).

The third patient, G.M., was a ten-year old boy who had suffered a left internal carotid artery thrombosis 19 months earlier. At the time of testing, he showed only a mild impairment of speech production, with nearly normal repetition and grossly adequate language comprehension. His major deficit, when evaluated by error scores, involved difficulty with visual words. His scanning data, however, were similar to those of the other patients. Again, the auditory spelled samples required the most correct-choice fixations, followed by the auditory pronounced samples, when the choices were printed words. With picture choices, only the dictated–spelled samples produced a major increase in fixations on the correct choice. With single-letters, he glanced at the correct choice more often in response to auditory than to visual samples while making no errors in either type of test.

The changes in scanning on different types of matching tasks required two types of controls. First, we gave normal subjects the same matching tests to ensure that nothing in the tests themselves produced the changes in scanning. Two normal adults showed only slight differences among the tasks, tending to refixate the correct key on less than 20 per cent of the trials (subjects M.L. and C.K. in Fig. 1). Second, we were curious to see whether normal subjects, given tasks of sufficient difficulty, might show scanning patterns not unlike those of our patients. The language tasks used here were not sufficiently challenging to test this hypothesis, so we used a circle–ellipse discrimination test instead. The subject's task was to pick a circle out of a group of ellipses which varied in height-to-width ratio on different trials from 0.17 to 0.95 [6]. Normal subjects and one aphasic patient (R.W.) glanced at the correct choice more frequently as the ellipses approached the dimensions of a circle (Fig. 2). This finding supports our supposition that the patients' tendency to refixate correct choices on certain tasks reflected the greater difficulty of such tasks.

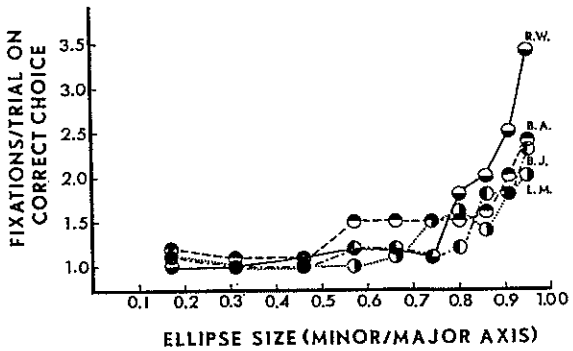

FIG. 2. Average number of fixations per trials on the correct choice, for correct trials only, by four subjects. The correct choice was always a circle, and the incorrect choices, which varied in size from trial to trial, were ellipses. The horizontal axes of the ellipses were the same as the circle (one inch).

Physical peculiarities of the stimuli themselves could not have accounted for the systematic variations in the patients' scanning patterns. The delayed matching procedure ensured that the sample stimuli themselves were never present while the patients inspected the choice stimuli, and differences appeared between tasks in which the choice displays were

identical. Increased scanning of the correct choices thus seemed related to the aphasic patients' difficulty in performing specific language tasks, as reflected in certain crossmodal auditory-visual associations, or in tasks involving printed words.

DISCUSSION

The three patients tested in this study all showed increased numbers of eye fixations on the correct choice in certain language-mediated matching tasks. Some of these tasks were clearly difficult for the subjects, as indicated by high error scores. In other tasks, however, error scores were low. In some cases the subjects had formerly made errors on these tasks but had improved to "normal" performances by error criteria alone. Eye movement recordings thus seemed to detect language difficulties sufficiently subtle to escape detection by standard error–score criteria.

It is not entirely clear why fixation frequencies increased on tasks with which the subjects had previously shown difficulty but now performed errorlessly, or on which their error scores had never indicated a deficit. Such altered scanning may have indicated simply a residual uncertainty as to the selection of the correct choice. Another possibility, perhaps more interesting, is that improvements in accuracy, and even initially low error scores on certain tests, may have reflected a new method the subject had devised to perform the matching task, perhaps by attending to different aspects of the visual stimuli than those he would normally use. Such compensatory changes might account for some of the discrepancies between fixation and error scores.

Few studies have examined the scanning patterns of aphasic patients. TYLER [1] noted that patients with severe "receptive" aphasias showed highly disorganized searching of pictorial displays, while patients with "expressive" aphasias showed largely normal patterns, but his studies did not involve specific language tasks. Numerous authors [7–13] have noted defective scanning of pictures and lines of print in patients with visual agnosias, simultanagnosias, Balint's syndrome, and other posterior cortical lesions. These studies, however did not examine scanning in aphasic patients; hence comparison with our data is not possible.

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Résumé—Chez des sujets aphasiques, on constatait une altération du balayage d'un panneau dans une tâche d'appariement á l'exemple, uniquement lorsque l'on changeait le stimulus pris comme exemple. Les malades regardaient plus fréquemment le choix correct pendant les performances à des épreuves où les scores d'erreurs montraient qu'ils étaient déficitaires. Les changements de balayage survenaient même sur des épreuves que les malades accomplissaient sans erreur au moment du test mais pour lesquelles ils avaient eu antérieurement des difficultés. Les patterns de balayage étaient ainsi plus sensibles que les scores d'erreurs pour la détection des difficultés du langage.

Zusammenfassung—Aphasische Kranke zeigten bei einem vergleichenden Vorlagetext verändertes Prüfungsverhalten visueller Objektzuwendung, wenn man nur den Vorlagetyp änderte. Bei Durchführung der Testaufgaben blickten die Patienten häufiger auf die richtige Ergebniswahl, während objektiv Fehler nachgewiesen werden konnten. Solche Änderungen des Prüfungsverhaltens zeigten sich sogar bei Übungen, die die Patienten zum Zeitpunkt der Testung fehlerlos ausführten, bei denen sie aber vorher Schwierigkeiten hatten. Für die Aufdeckung von Sprachschwierigkeiten ist demnach das Prüfungsverhalten aufschlußreicher als Fehlermessungen.